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Climate Change and Wildlife Health: Direct and Indirect Effects

Climate change will have significant effects on wildlife, domestic animal, and human diseases, according to scientists. The Intergovernmental Panel on Climate Change predicts that unprecedented rates of climate change will result in increased average global temperatures; a rise in sea levels; changes in global precipitation patterns, including increased amounts and variability; and increased midcontinental drying during summer (Intergovernmental Panel on Climate Change, 2007). Scientists suspect that increasing temperatures, in combination with changes in rainfall and humidity, may have significant impacts on wildlife, domestic animal, and human diseases. Because of expanding human populations, these changes could aggravate already limited water resources and increase habitat destruction, providing yet more opportunities for infectious diseases to cross from one species to another.

Awareness has been growing in recent years about zoonotic diseases—that is, diseases that are transmissible between animals and humans. The rise of such diseases is the result of an increasingly close relationship among wildlife, domestic animals, and people, allowing more contact with diseased animals, or infected vectors and people (Daszak and others, 2000). Thus, it is impossible to separate the effects of global warming on wildlife from its effects on the health of domestic animals or people (fig. 1).

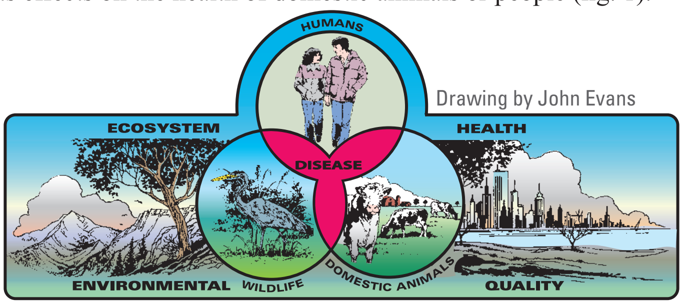

Fig. 1. Ecosystem health reflects environmental quality, an important factor in the well-being of humans, domestic animals, and wildlife. The interface between these components requires a holistic approach of "one health" for the benefit of all (Friend, 2006).

Climate change effects must be distinguished from other human activities that threaten human and animal health, such as habitat destruction and urbanization, the introduction of exotic and invasive species, and pollution. Clearly, these human activities directly affect ecosystem health and thereby indirectly affect human and animal health as well.

Climate change must also be viewed within the context of other physical and climate cycles, such as the El Niño Southern Oscillation (El Niño) (Rasmussen and Carpenter, 1982) and cycles in solar radiation (Carslaw and others, 2002) that have profound effects on the Earth's climate and human, domestic animal, and wildlife health.

Still, convincing evidence exists for climate change effects on wildlife disease in several areas, four of which are addressed here: geographic range and distribution of wildlife diseases, plant and animal phenology (Walther and others, 2002), wildlife host-pathogen interactions, and disease patterns in wildlife. Other factors of concern, such as ecosystem composition and pathogen virulence, are addressed in climate change literature.

Geographic Range and Distribution of Wildlife Diseases

In the Northern Hemisphere global warming has likely played a role in northern geographic shifts of disease vectors and parasitic diseases that have complex life cycles. For example, the geographic range of the lung parasite, *Parelaphostrongylus odocoilei*, of caribou has shifted northward since 1995 from the Pacific Coastal Range of the United States and British Columbia to include Alaska and the Yukon and Northwest Territories of Canada (fig. 2).

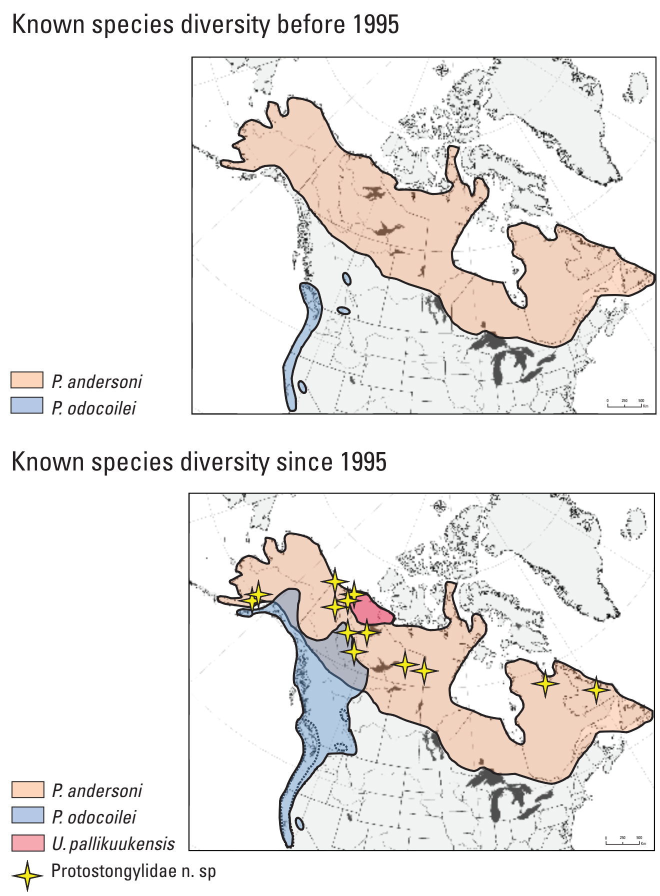

Fig. 2. Geographic ranges for protostrongylid parasites in northern ungulates including caribou, wild thinhorn sheep, mountain goat, woodland caribou, black-tailed and mule deer (Hoberg and others, 2008).

In addition, the tick vector, *Ixodes scapularis*, of Lyme disease and several other tick-borne zoonotic diseases in North America has been expanding north into southern Ontario and, more recently, into western Ontario and Manitoba (Ogden and others, 2009).

Besides north-south shifts, scientists also predict disease distribution changes in altitude. For example, climate warming may lead to year-round transmission of avian malaria at higher elevations in the Hawaiian Islands, further threatening endangered native Hawaiian birds that have little or no resistance to the introduced disease. Currently, on the island of Hawai'i, avian malaria, caused by the parasite *Plasmodium relictum*, is limited to warmer elevations below 1,500 meters (fig. 3) (Van Riper III and others, 1986). If the higher elevations become warmer as predicted, mosquito activity and parasite development in these areas will increase. Conservationists are concerned that climate change may lead to increased avian malaria transmission throughout the year at increasingly higher elevations (fig. 3).

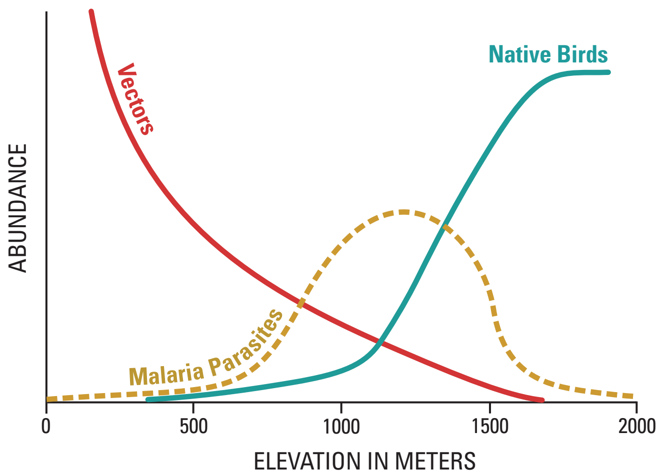

Fig. 3. Abundance of avian malaria parasites in Hawaiian birds, mosquito vectors, and native Hawaiian birds, in relation to elevation on the island of Hawai'i (Van Riper and others, 1986)

Phenology: Effects on Wildlife Disease

The timing of recurring seasonal biologic cycles of a number of plant and animal species has already been affected by climate change (Walther and others, 2002). The study of these seasonal cycles is called phenology. The timing of biological cycles, such as the arrival of a bird species in the spring and the availability of its preferred food source, is critical for successful breeding and survival. Variability in the timing of these biological cycles also can lead to an increase or decrease in the risk for infectious disease, particularly vector-transmitted disease. In Europe, transmission of tick-borne encephalitis (TBE) to humans is often increased when warmer temperatures in the early spring result in the overlap of feeding activity of nymphal (virus infected) and larval (uninfected) *Ixodes ricinus* ticks. Under these weather conditions, infection is more readily passed from infected ticks to uninfected ticks through small rodents. Because the viral infection is brief in tick-infested rodents, feeding of both stages of tick at the same time results in more infected larval ticks and greater risk for TBE infection in humans (Randolph, 2009). Cooler spring temperatures result in less overlap of feeding activity of nymphal and larval ticks. Therefore, under these conditions the virus-infected rodents have time to recover from infection and are less likely to pass the virus to feeding larval ticks (fig. 4).

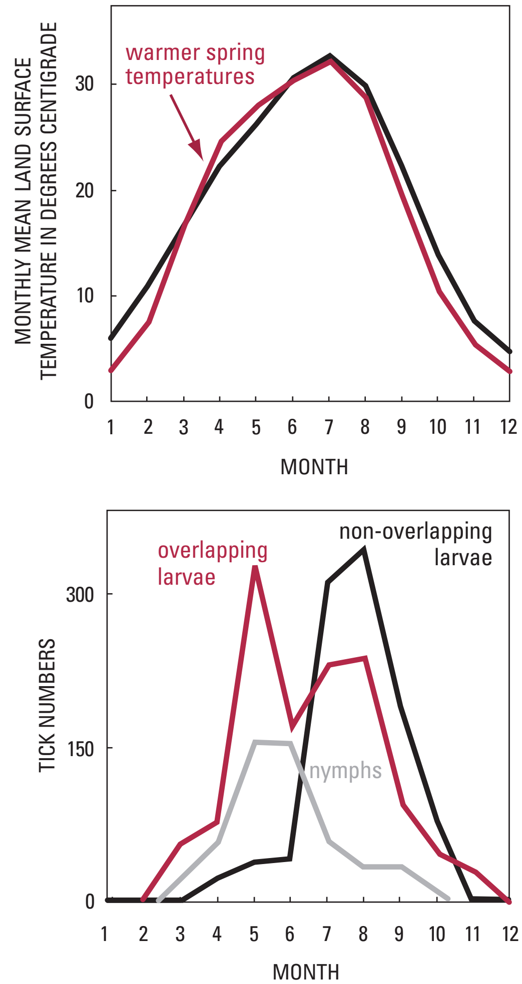

Fig. 4. Human risk for tick-borne encephalitis in Europe is heightened in some years by slightly warmer temperatures in early spring (red line and arrow, top figure) that are associated with overlapping feeding of infected nymphal ticks and uninfected larval ticks (grey and red line, bottom figure). A slower rise in spring temperatures (black line, top figure) is associated with non-overlapping feeding (graphs provided by S. Randolph, 2010).

At a number of sites in North America, the same seasonal temperature effect has been observed in the transmission of the bacterium *Borrelia burgdorferi*, the cause of Lyme disease, from infected nymphal *Ixodes scapularis* ticks to uninfected larval ticks. When feeding of larval ticks occurs at or nearly at the same time, it not only contributes to the successful transmission of the pathogen to larvae, but it also results in greater genetic diversity in this zoonotic pathogen (Gatewood and others, 2009). Climate change has the potential to affect these natural cycles by altering seasonal weather patterns.

Wildlife Host–Pathogen Interactions

In nature, pathogens can be transmitted directly from one diseased animal to another, or they may be transmitted indirectly though intermediate hosts, such as infected prey, or through vectors such as biting insects. Indirect transmission cycles are often affected by environmental conditions such as temperature and rainfall. Higher temperatures associated with climate change may contribute to an increase in disease-producing agents within intermediate hosts and vectors, or increased survival of animals that harbor disease. For example, warmer summer temperatures in the Arctic now allow the lung nematode (*Umingmakstrongylus pallikuukensis*) larvae often found in muskoxen to develop to the infectious stage within the intermediate host, the marsh slug (*Deroceras laeve*), at a rate that has reduced the parasite's life cycle from 2 years to 1 year (Kutz and others, 2005).

Survival of another nematode, *Parelaphostrongylus tenuis*, the brain worm of white-tailed deer, may also be increased by recently warmer temperatures and milder winters in the North Central United States and southern Canada. The parasite, which overwinters as larvae in snails, causes neurological disease in moose (*Alces alces*) (fig. 5). Moose are already heat stressed by climate change (Lenarz and others, 2009), and may be more susceptible to parasitic and infectious diseases (Murray, 2009), including the brain worm of white-tailed deer.

Fig. 5. Healthy North American bull moose (USFWS). Diseased North American cow moose in the final stages of a brain worm infection in St. Louis County, Minnesota (Mike Schrage, Wildlife Biologist, Fond du Lac Band).

Disease Patterns in Wildlife

Predicting the effects of climate change on disease patterns across a geographic region is difficult because the effects are likely to be highly variable. This may be especially true among marine ecosystems. Since the 1980s, coral reefs in the western Atlantic Ocean have suffered massive declines due to disease (Porter and others, 2001). It is likely that coral mortalities were initially due to widespread mortality of sea urchins that allowed algal overgrowth of reefs followed by environmental degradation and increased susceptibility to disease (Lessios, 1988). Since the early 1980s, mass coral bleaching has been observed worldwide, especially following the major 1998 El Niño event, and has been linked to elevated sea-surface temperatures (Hoegh-Guldberg, 1999). Corals are able to survive in nutrient-deficient waters because of their symbiotic association with photosynthetic algae. Corals that have lost these algae due to increased water temperature, changes in salinity, or pollution are unable to attain enough energy from their environment and may be susceptible to disease leaving white coral skeletons, referred to as coral bleaching (fig. 6). Elevated temperatures will likely increase coral bleaching, which can lead to coral die-offs (Baker and others, 2008). Corals that fail to recover sufficiently may lead to loss of coral reefs and associated tropical marine life that depend on these animals for food and shelter. As a result, local economies that depend on coral reefs for sustenance or tourism could be significantly affected by climate change (Pandolfi and others, 2005).

Fig. 6. Extensive coral bleaching on a reef, St. John, U.S. Virgin Islands (Caroline S. Rogers, USGS).

Questions to Ponder about Climate Change

1. *Long-term interdisciplinary projects can help determine climate's impacts on biological factors associated with disease emergence (that is, species abundance, interactions and movements, vector populations). How might various physical, social, and economic factors contribute to disease emergence, persistence, and spread?*

2. *How are threatened and endangered free-ranging wildlife populations currently threatened by disease? How might climate change affect the current situation?*

3. *How will climate change play a role in the threat of wildlife-associated water- and vector-borne diseases for free-ranging wildlife, other animals, and humans?*

4. *How will climate change play a role in the lives of native peoples who are dependent upon wildlife as a major source for food? Will wildlife population declines or wildlife-associated food-borne disease threaten native peoples?*

References

Baker, A.C., Glynn, P.W., and Riegl, B., 2008, Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook: Estuarine, Coastal and Shelf Science, v. 80, p. 435–471.

Carslaw, K.S., Harrison, R.G., and Kirkby, J., 2002, Cosmic rays, clouds, and climate: Science, v. 298, no. 5599, p. 1732–1737.

Daszak, P., Cunningham, A.A., and Hyatt, A.D., 2000, Wildlife ecology—emerging infectious diseases of wildlife—threats to biodiversity and human health: Science, v. 287, no. 5452, p. 443–449.

Friend, M., 2006, Disease emergence and resurgence: the wildlife-human connection: Reston, Va., U.S. Geological Survey, Circular 1285, p. 400.

Gatewood, A.G., Liebman, K.A., Vourc'h, G., Bunikis, J., Hamer, S.A., Cortinas, R., Melton, F., Cislo, P., Kitron, U., Tsao, J., Barbour, A.G., Fish, D., and Diuk-Wasser, M.A., 2009, Climate and tick seasonality are predictors of *Borrelia burgdorferi* genotype distribution: Applied and Environmental Microbiology, v. 75, no. 8, p. 2476–2483.

Hoberg, E.P., Polley, L., Jenkins, E.J., Kutz, S.J., Veitch, A.M., and Elkin, B.T., 2008, Integrated approaches and empirical models for investigation of parasitic diseases in northern wildlife: Emerging Infectious Diseases, v. 14, no. 1, p. 10-17.

Hoegh-Guldberg, O., 1999, Climate change, coral bleaching and the future of the world's coral reefs: Marine and Freshwater Research, v. 50, p. 839–866.

Intergovernmental Panel on Climate Change, 2007, Climate change 2007: synthesis report: contribution of Working Groups I, II, and III to the Fourth assessment report of the Intergovernmental Panel on Climate Change: Geneva, Switzerland, Intergovernmenatl Panel on Climate Change, 104 p.

Kutz, S.J., Hoberg, E.P., Polley, L., and Jenkins, E.J., 2005, Global warming is changing the dynamics of Arctic host-parasite systems: Proceedings of the Royal Society B-Biological Sciences, v. 272, no. 1581, p. 2571–2576.

Lenarz, M.S., Nelson, M.E., Schrage, M.W., and Edwards, A.J., 2009, Temperature mediated moose survival in northeastern Minnesota: Journal of Wildlife Management, v. 73, no. 4, p. 503–510.

Lessios, H.A., 1988, Mass mortality of *Diadema antillarum* in the Caribbean: What have we learned?: Annual Review of Ecology and Systematics, v. 19, p. 371–393.

Murray, D.L., Cox, E.W., Ballard, W.B., Whitlaw, H.A., Lenarz, M.S., Custer, T.W., Barnett, T., Fuller, T.K. , 2009, Pathogens, nutritional deficiency, and climate influences on a declining moose population: Wildlife Monographs, v. 166, p. 1–30.

Ogden, N.H., Lindsay, L.R., Morshed, M., Sockett, P.N., and Artsob, H., 2009, The emergence of Lyme disease in Canada: Canadian Medical Association Journal, v. 180, no. 12, p. 1221–1224.

Pandolfi, J.M., Jackson, B.C., Baron, N., Bradbury, R.H., Guzman, H.M., Hughes, T.P., Kappel, C.V., Micheli, F., Ogden, J.C., Possingham, H.P., and Sala, E., 2005, Are U.S. coral reefs on the slippery slope to slime?: Science, v. 307, p. 1725–1726.

Porter, J., Dustan, P., Jaap, W., Patterson, K., Kosmynin, V., Meier, O., Patterson, M., and Parsons, M., 2001, Patterns of spread of coral disease in the Florida keys: Hydrobiologia, v. 460, p. 1–24.

Randolph, S.E., 2009, Tick-borne disease systems emerge from the shadows: the beauty lies in molecular detail, the message in epidemiology: Parasitology, v. 136, no. 12, p. 1403–1413.

Rasmussen, E.M., and Carpenter, T.H., 1982, Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Niño: Monthly Weather Review, no. 110, p. 354–382.

Van Riper III, C., Van Riper, S.G., Goff, M.L., and Laird, M., 1986, The epizootiology and ecological significance of malaria in Hawaiian land birds: Ecological Monographs, v. 56, no. 4, p. 327–344.

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O., and Bairlein, F., 2002, Ecological responses to recent climate change: Nature, v. 416, no. 6879, p. 389–395.

By Erik Hofmeister, Gail Moede Rogall, Kathy Wesenberg, Rachel Abbott, Thierry Work, Krysten Schuler, and Jonathan Sleeman.

For additional information contact:
Erik Hofmeister, (608) 270-2476, ehofmeister@usgs.gov
Gail Moede Rogall, (608) 270-2438, gmrogall@usgs.gov

USGS National Wildlife Health Center
6006 Schroeder Rd
Madison, WI 53711
http://www.nwhc.usgs.gov/

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